MITCHELL CREEK

HYDROLOGIC INVESTIGATION

Incorporating both water quantity and quality considerations in urbanizing watersheds.

by

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EXECUTIVE SUMMARY

Hydrologic modeling is useful for local communities to evaluate the effects of planned zoning on streamflow within a watershed. Urbanization, if left unchecked, can cause detrimental impacts to a watercourse. These impacts include increased peak flows, reduced baseflow, channel erosion, elimination of pools and riffles, less diverse fish and aquatic communities, increased water temperatures, increased soil erosion and increased pollutant loads to the watercourse. Some of these impacts are due to the increased volume of runoff which results from urbanization and its associated paving and land use changes. Other impacts are due to the increased pollutants and sediments which wash off impervious areas and construction sites.

A hydrologic model was developed which divided the Mitchell Creek Watershed into 29 subwatersheds. Based on land use and soil information from each subwatershed, the model develops flows from each area. These flows can be combined at various locations to represent a composite runoff hydrograph. With this model, the land use for a subwatershed can be changed and the potential impact on downstream flows can be evaluated. The model can also be used to evaluate regional retention sites.

The model was used to evaluate what affect potential urbanization would have on peak streamflows in Mitchell Creek. Three scenarios were evaluated:

1) Existing land use conditions using 1978 land use information;

2) Future land use assuming ¼ acre residential development throughout the watershed;

3) Future land use based on Township Zoning Plans.

The scenarios were modeled assuming no retention/detention requirements. The 2-year, 25-year and 100-year 24 hour rainfall events were used with the model. Model results down to Four Mile Creek (da = 12.1 square miles) are summarized below:

	1978 Conditions		¼ Acre Development		Zoned Development	
Mitchell Creek	2-yr.	100-yr.	2-yr.	100-yr.	2-yr.	100-yr.
d/s of Four Mile Creek, DA = 12.1 mi^2	90 cfs	820	210	1340	420	1780

If no retention/detention requirements were imposed with the zoned conditions, the above comparison indicates that there would be a two-fold increase in peak flows produced by the 100-year rainfall and a four-fold increase in flows produced by the 2-year rainfall. This increase in flow would cause additional flooding and channel scouring which would affect the quality of the creek. The amount of flow increase for some of the individual subwatersheds was even more dramatic, especially those which are currently meadow and are zoned to be commercial. For these subbasins, the 2-year peak flows increased by as much as a factor of 10. The reason for this is that with sandy soils in a meadow condition most of the 2-year rainfall infiltrates into the soil. The majority of the soils in the Mitchell Creek watershed are sandy or sandy loams which means that adding impervious surface will cause a much higher percentage of runoff.

Several road crossings which had small culverts with a high road fill were evaluated for their ability to attenuate (lower) peak flows. The model results indicate that many of those roads are effective in reducing peak flows and in that respect are acting like detention ponds. Any future road project which enlarges an existing small culvert that has more than 4 feet of road fill should be evaluated for downstream impacts. A larger bridge or culvert will allow a higher flood peak to pass, thereby increasing flows and potential flooding. Another consideration is increased development will increase the frequency and duration of flooding upstream of the crossing.

Some states and communities across the country have retention/detention requirements to meet both water quantity and quality concerns. Many Michigan communities have regulations dealing with increased water quantity caused by urbanization, but very few have addressed retention/detention requirements to deal with water quality issues. In order to address both concerns, a comprehensive approach is needed. Water quantity concerns are usually dealt with by requiring that retention/detention be used to limit peak runoff rates after urbanization to what they were before development or less. This requirement is usually applied to the entire community even though detention at the downstream end of the watershed could actually increase flows due to delaying of the peak (Figures 7a, b, c). Modeling can be used to address this potential problem, at least on a regional scale.

In order to address water quality concerns, several things can be done which are often called Best Management Practices (BMP's). Some of these are listed below.

1) Provide a buffer or greenbelt along all streams, drains, wetlands and lakes. Requirements for buffer widths vary from 25 to 200 feet (on small streams water temperatures may increase 1.5° F per 100 feet when flowing through unshaded reaches).

2) Maintain as much vegetation and green area as possible.

3) Use grassed swales instead of curb and gutter.

4) Disconnect downspouts from sewers.

5) Use sediment sumps in storm sewers.

6) Provide shade for retention/detention ponds and their inlets and outlets.

7) Restrict development in environmentally sensitive areas.

8) Possible use of cluster development which minimizes the disturbed area.

9) Use strict soil erosion controls at construction sites.

10) Avoid clear cutting a development site all at once. Do the construction in a staged manner, stabilize one area before moving on.

11) Use a sediment basin at construction sites. A recent Maryland study suggested that a basin volume sized at 3600 ft^3/acre be used.

12) Provide retention/detention for small rainfall events up to the 2-year storm.

Item number 12 deals with retention/detention requirements to address water quality concerns. Small runoff events pick up and deliver the majority of the pollutants to a watercourse. Nationally, the amount of runoff to be treated varies from .5 inches per impervious acre up to the amount of runoff provided by a 2-year 24 hour storm. The runoff volume can be treated in two ways:

1) The runoff is directed to an infiltration basin or trench with no outlet. The water infiltrates into the ground within 72 hours. In order for this method to be used, the infiltration rate of the underlying soils should be .52 inches/hour. Most of the soils in the Mitchell Creek Basin are sands and loamy sands which should meet this requirement. The bottom of the basins should be 4 feet above the seasonally high ground water table. Infiltration provides for the highest removal of pollutants in the runoff and causes the least impact on increasing stream temperatures.

2) The runoff is directed to an extended detention or wet retention pond. The volume of runoff should be filtered out over a 24-48 hour period to allow for settling of some of the pollutants.

Typical dry detention basins with an open pipe at the bottom which allows everything to flow out does very little for water quality. Infiltration basins and retention/detention ponds can be designed to handle both water quality and water quantity concerns.

The local governmental agencies in the Mitchell Creek watershed have a draft ordinance which states the following: "... as a minimum any retention, detention or infiltration basin shall have the storage capacity to hold the increase in runoff caused by a proposed project based on the 25-year 24 hour storm. The volume is to be released over a 24 hour period at a peak release rate of .2 cfs/acre or the 2-year 24 hour peak based on grassed conditions, whichever is less." It further calls for storing back to back 100-year storms when downstream flooding or water quality concerns are critical. If this ordinance is adopted, it should address many of the water quantity or quality concerns which are identified in this paper.

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Introduction

This report evaluates the existing hydrology for the Mitchell Creek watershed and analyzes the effects on flood flows due to the increased urbanization which has and will take place. It is the intent of the report to show how modeling can be used to document these effects and how modeling can be used as part of the community planning process. Local officials will be provided the Mitchell Creek watershed model to aid their decision making process regarding land use changes.

Unregulated development can lead to increased flows and have damaging impacts on the water quality of a stream system. Urbanization tends to fill in areas which provide storage, and pave over other areas which prevent infiltration. These actions produce higher runoff volumes with greater flood peaks that occur more quickly. Schueler (1987/90) indicates that increased urbanization has the following impacts on a stream system:

- Peak discharges are increased 2-5 times over predevelopment peaks.

- The frequency of bankfull flooding events may increase from once every two years to 3-5 times each year. A stream that over the years has naturally adapted to handle bankfull flooding will now be reshaped due to increased quantities (50% more runoff) and velocity of water. There will be channel down cutting and widening (2-4 times wider), streambank erosion, falling trees and slumping banks.

- Runoff will reach the stream much faster (up to 50%).

- Reduced baseflow because less infiltration is taking place.

- Pools and riffles are eliminated due to sedimentation and changes in channel characteristics. This has a direct affect on the aquatic community and the number and types of organisms found there.

- Fish communities become less diverse with a sharp decrease or elimination of sensitive fish species.

- The amounts of pollutants entering the stream system during and after development increase by an order of magnitude.

- The temperature of an urban stream may increase linearly .14 degrees Fahrenheit per 1% increase in imperviousness (Galli, 1990).

Some Best Management Practices (BMP's) will be discussed which help control some of the above impacts. A publication entitled "Stormwater Management Guidebook", MDNR 1991, provides more detailed design considerations for BMP's related to stormwater detention/retention.

This report is designed to encourage local officials, planners and engineers to evaluate water quality issues related to urbanization. Many communities in Michigan have started to address water quantity concerns, however, very few have taken the next step to address water quality. Some states have adopted laws to address this concern, but Michigan currently has none.

Background

The Mitchell Creek Watershed is located in Grand Traverse County near Traverse City, Michigan (Figure 1). The majority of the watershed lies in Garfield and East Bay Townships. The total drainage area of Mitchell Creek at its mouth is 15.8 square miles. The watershed has fairly steep headwaters which are drained south to north by several intermittent streams. The average slope of the headwater areas south of Hammond Road and east of Four Mile Road is 2.6% (140 ft/mile). The central portion of the watershed (south of South Airport Road) is much flatter with large areas of wetlands. Below its confluence with Four Mile Creek, Mitchell Creek splits into two branches (East and West) which come together again about 1200 feet upstream of its mouth (just upstream of the lower Three Mile Road crossing) (Figure 2).

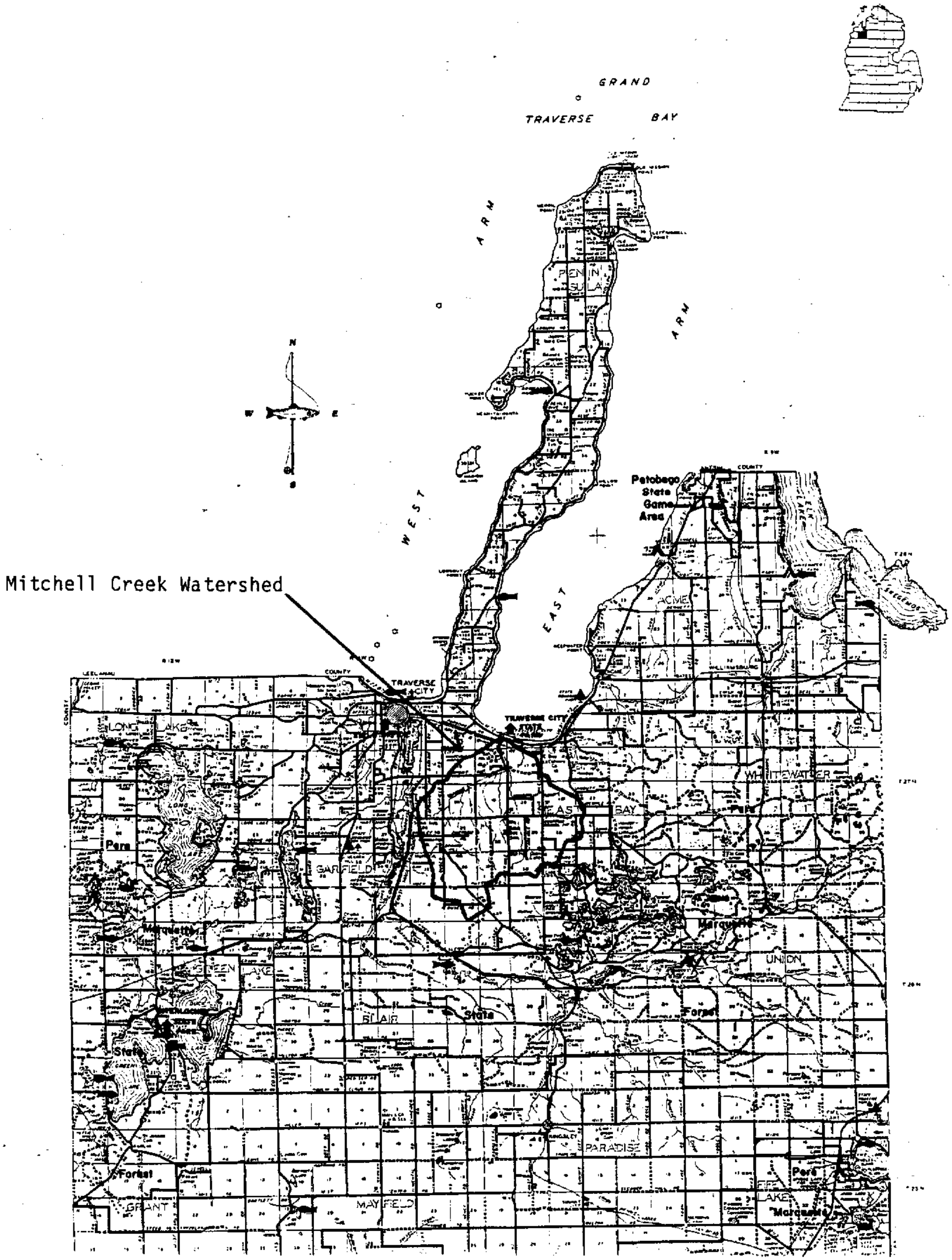
Modeling

In order to evaluate the affects of land use changes on flows in Mitchell Creek, a HEC-1 model was set up. HEC-1 is a computer model developed by the U.S. Army Corps of Engineers which simulates runoff for a given design storm. The model, which can be run on a personal computer, is able to develop runoff from several subbasins and combine them to develop a composite hydrograph at various locations. One can change the land use for a subwatershed and determine the affects on flows at some downstream point in the watershed.

The Mitchell Creek Watershed was divided into 29 subwatersheds (Figure 3) ranging in size from .02 square mile (13 acres) to 1.03 square miles (659 acres). The downstream end point for this model is at the confluence of Mitchell Creek and Four Mile Creek just upstream of where Mitchell Creek splits into the East and West Branch. The contributing drainage area at this site is 12.1 square miles. Land found to be noncontributing (in terms of storm runoff) either through map inspection or visual inspection, was not included in the model. Noncontributing area is usually isolated from the watershed because there are no or very restrictive road culverts or it is an area which drains to a large pothole with no outlet. The amount of noncontributing area is estimated to be 2.25 square miles. These are shown as shaded areas in Figure 3.

FIGURE 1

GRAND TRAVERSE COUNTY



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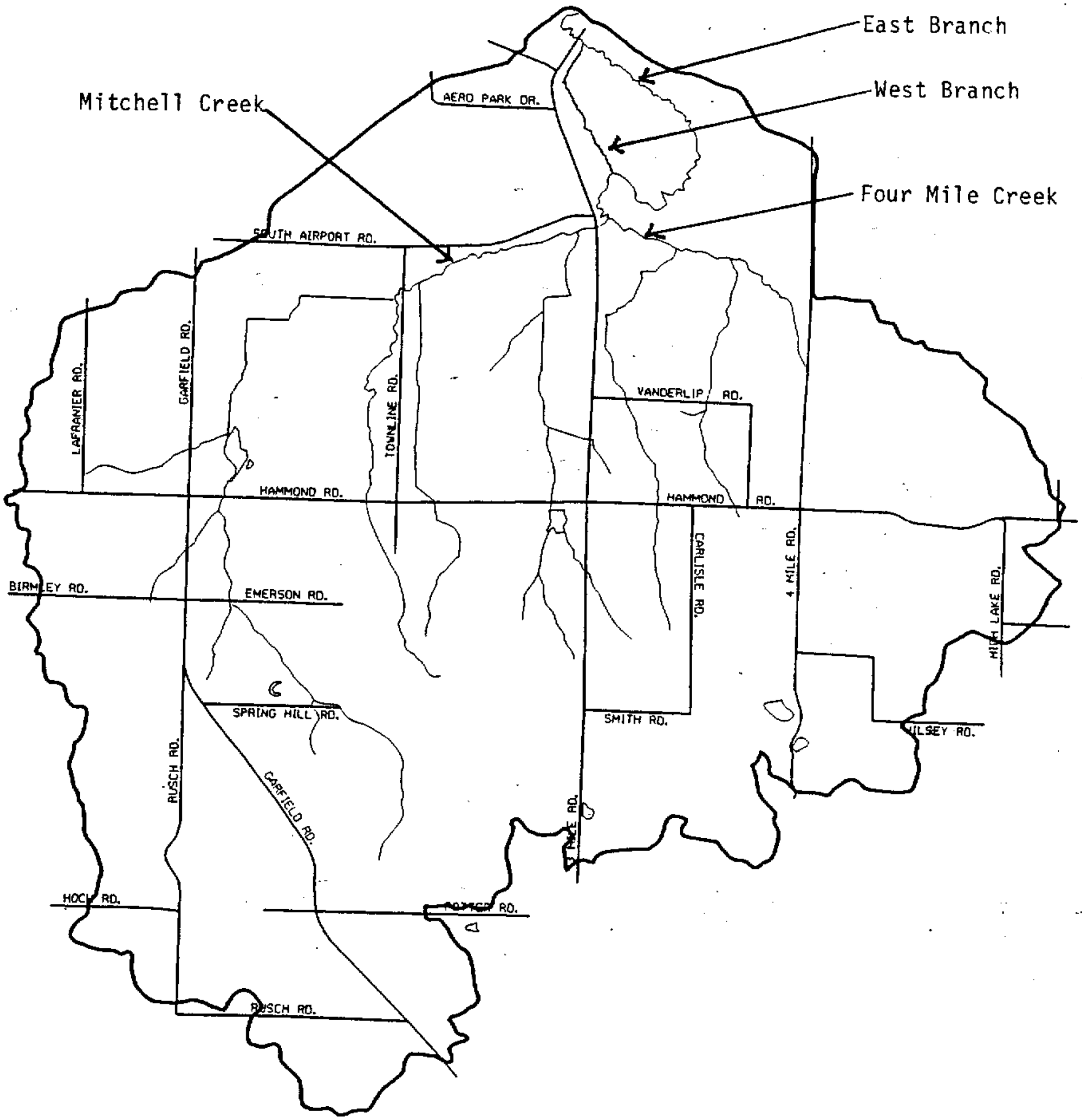


FIGURE 2

MITCHELL CREEK WATERSHED

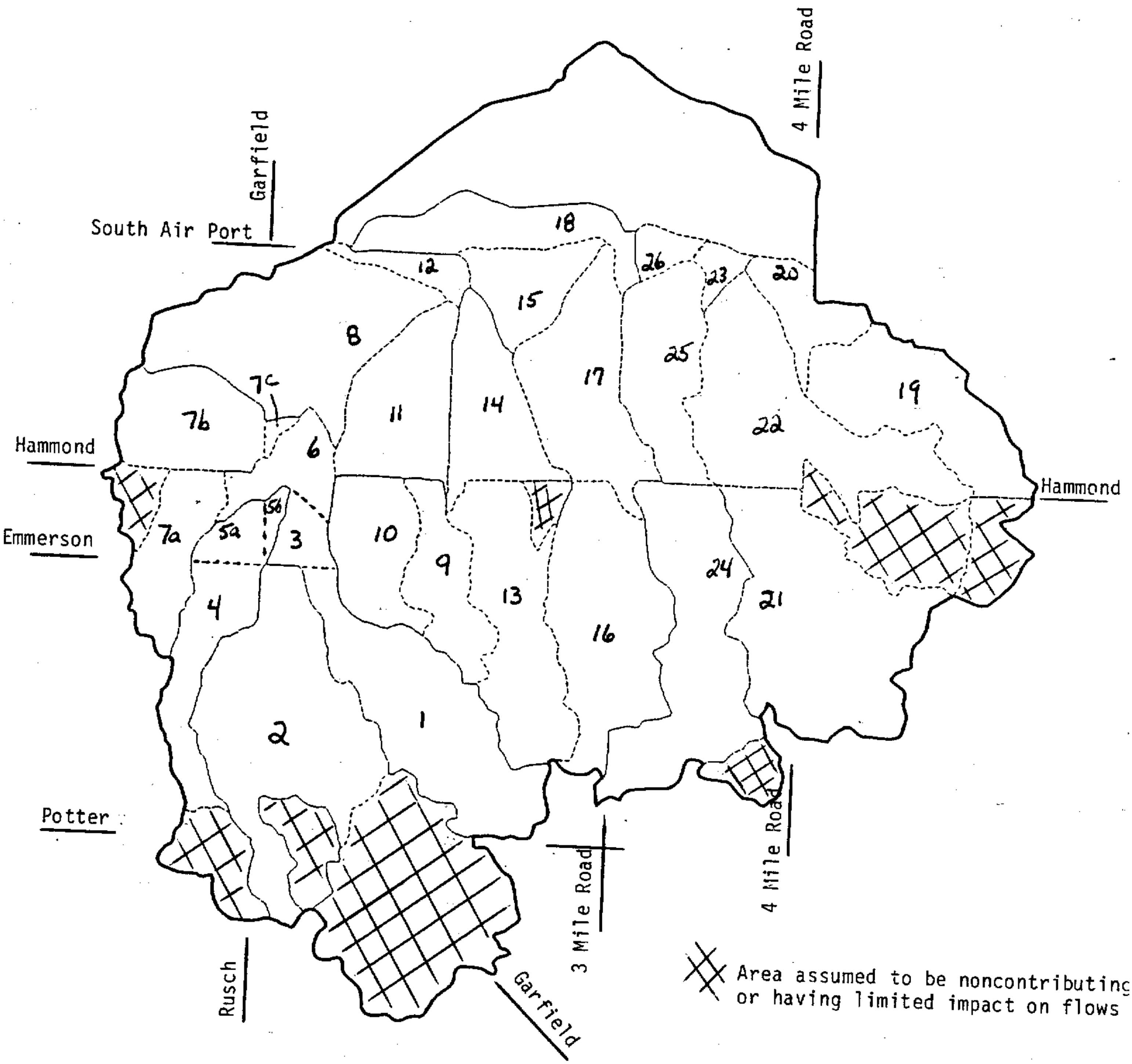


FIGURE 3

SUBWATERSHED BOUNDARIES

Inputs into the HEC-1 model for each subbasin include a curve number, which relates runoff to soils and land use for a particular rainfall, and lag (.6 x time of concentration). Other required information for the model are reach lengths and slopes from one subbasin to the next and stage-storage-discharge relationships for any culverts or structures which may attenuate (lower) flood peaks.

Soils

The soils in this area are primarily sand, loamy sand, gravelly sandy loam and sandy loam with some muck soils in the low lying areas. The Soil Conservation Service groups all soils into four main categories A, B, C and D related to their runoff potential. The Type A soils have a low runoff potential and high infiltration rates, while the D soils have a high runoff potential and very low infiltration rates. The following table indicates the texture class, the minimum infiltration rate and the hydrologic soil grouping for various soils (Rawls, 1982):

TABLE 1

Texture Class vs Infiltration vs Soil Grouping

Texture Class	Minimum Infiltration Rate inches per hour	Soil Grouping
Sand	8.27	A
Loamy Sand	2.41	A
Sandy Loam	1.02	B
Loam	.52	B
Silt Loam	.27	C
Sandy Clay Loam	.17	C
Clay Loam	.09	D
Silty Clay Loam	.06	D
Sandy Clay	.05	D
Silty Clay	.04	D
Clay	.02	D

The percentage breakdown for the soils in the Mitchell Creek Watershed are:

A	53%
B	32%
D	15%
	100%

Because of the high percentage of A and B soils in the Mitchell Creek watershed, the runoff potential is very low when left undeveloped. Urbanization with its associated paving and storm sewers will greatly increase the runoff potential from these soil types. As noted on Table 1, the infiltration rates of the A and B soils is very high. These high rates of infiltration are beneficial when designing retention/detention systems to reduce the affects of urbanization. Infiltration basins are recommended when treating runoff from developed sites. In order to be effective, this type of BMP must have underlying soils which have infiltration rates of .52 inches or more. The majority of the soils in this watershed appear to meet this criteria.

Land Use

Land use information was derived from the Michigan Resource Information System (MIRIS). These data are based on interpretation of 1978 aerial photographs. This was then used as the basis of establishing existing conditions prior to significant development. Table 13 (Appendix A) lists the land uses which are contained in the MIRIS data base. For this study several of the uses were grouped together and treated similarly as far as runoff potential. For example, all of the land uses listed under forest (411-429) were grouped together. Table 2 lists the 1978 land use in the Mitchell Creek Watershed down to and including Four Mile Creek.

TABLE 2

1978 land use data

Forested	30%
Herbaceous	23%
Crop	22%
Shrub	9%
Orchard	6%
Urban-Residential	6%
All Other	4%
	100%

Estimates of future land use were based on zoning maps for Garfield and East Bay Townships. The future zoning plans indicate a combination of residential (1, 2, 4 and 12 units/acre) and heavy commercial/light industrial through the central and lower parts of the watershed. The upper watershed has been zoned as agricultural-residential (2 acre lots). For the purpose of this study, this agricultural area was assumed to develop into 1 acre residential lots under future zoned conditions. Table 3 lists the estimated future land use for Mitchell Creek based on zoning plans.

TABLE 3

FUTURE LAND USE

Residential 1 per 2 acre	42%
Residential 1-2 per acre	16%
Residential 2-4 per acre	13%
Residential 12 per acre	9%
Heavy Commercial/Light Industrial	19%
Park	1%
	100%

Curve Number

The curve number is a term which relates the runoff potential for a given rainfall to the soils and land use for a given site. Table 4 lists some of the curve numbers which were used in this report. To convert the curve number to a runoff value for a given rainfall, figure 4 can be used. The following equations can also be used:

$S = (1000/CN)-10$, CN = curve number
Runoff (SRO) = $(P-.2S)^2/(P+.8S)$, P = design rainfall

TABLE 4

Land Use vs Soil Type vs Curve Number

MIRIS Land Use Code	MIRIS Land Use Type	Curve Number vs Soil Type A	B	C	D
111,112	Multi-Family	77	85	90	92
113	Single Family (¼ acre)	61	75	83	87
115	Mobile Home Park	77	85	90	92
121,122	Commercial	89	92	94	95
138	Industrial	81	88	91	93
21	Cropland	65	77	84	88
22	Orchards	43	65	76	82
23	Confined Feeding	68	79	86	89
24	Pasture	49	69	79	84
32	Shrub	30	58	71	78
31	Herbaceous	49	69	79	84
411-429	Forest	45	60	73	79
51-54	Water	100	100	100	100
193,194	Open Land	39	61	74	80
611	Wooded Wetland	45	60	73	79
612	Shrub, Scrub Wetland	30	58	71	78
621,622	Aquatic, Emergent Wetland	100	100	100	100

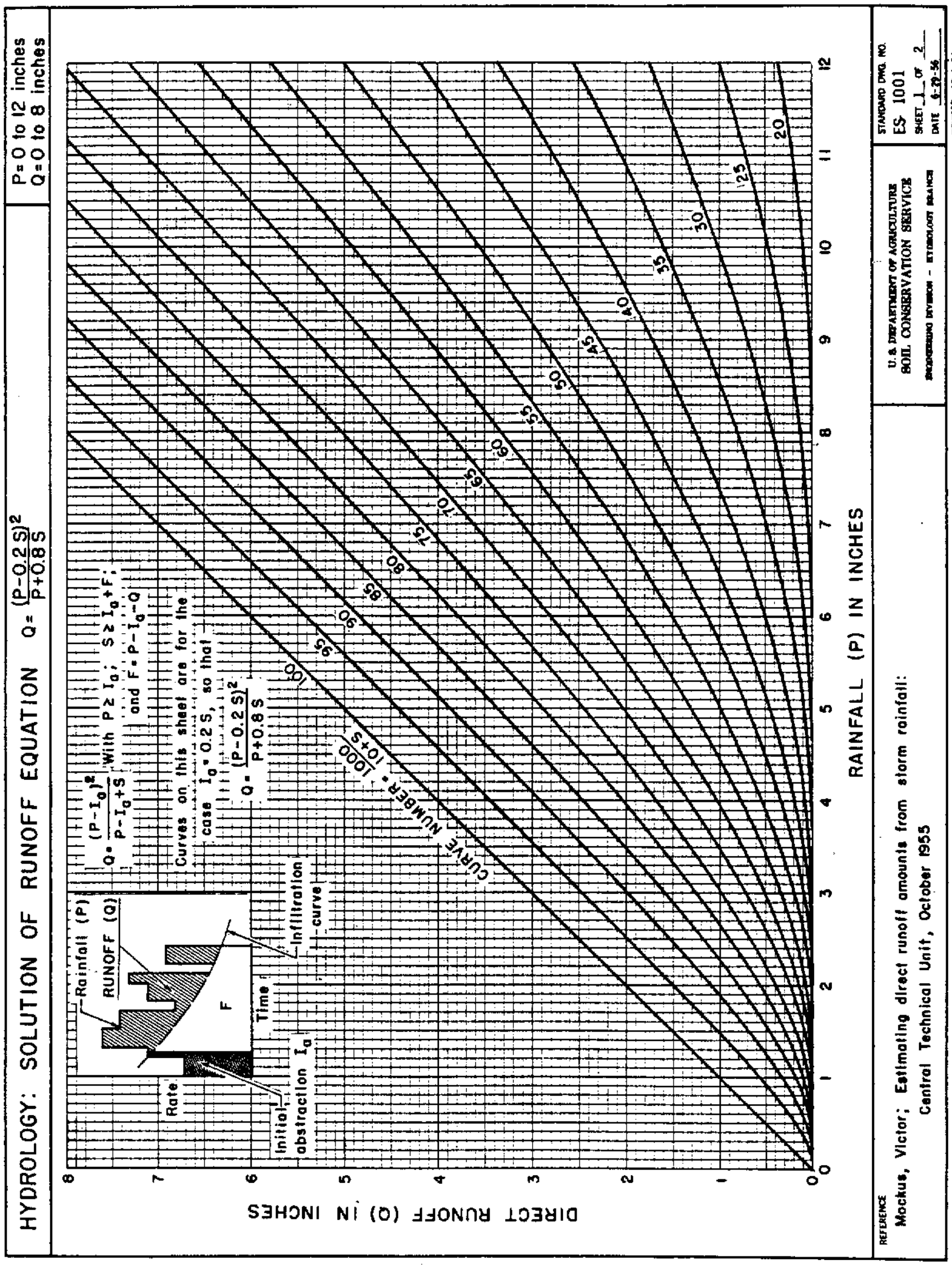


FIGURE 4

HYDROLOGY: SOLUTION OF RUNOFF EQUATION

Example:

Determine the runoff for a rainfall of 4.45 inches, B soils and ¼ acre residential lot.

From Table 4 CN = 75 for ¼ acre lot on a B soil

$S = (1000/75)-10 = 3.33$
$SRO = (4.45 - .2(3.33))^2/(4.45+8(3.33) = 2.01$ inches

The runoff amount would be 2.01 inches.

The following example shows how to compute the runoff from a .8 square mile (512 acre) area, and how to determine an average curve number for that area. The rainfall amount is 4.45 inches.

Soils Group	%	Mi^2	Land Use	%	Mi^2	CN	S.R.O.	Sq. Mi-In
A	30	.24	Forest	20	.05	45	.28	.01
			Crop	30	.07	65	1.30	.09
			Commercial	30	.07	89	3.25	.23
			Herbaceous	20	.05	49	.44	.02
B	70	.56	Forest	10	.06	60	1.00	.06
			Crop	25	.14	77	2.17	.30
			Urban (¼ Acre)	50	.28	75	2.00	.56
			Herbaceous	15	.08	69	1.56	.13
								1.41 sq. mi-in

The total volume of runoff for this .8 square mile area is
1.41 sq. mi-in = 75 acre-feet.

The average amount of runoff over this area is
1.41 sq. mi-in/.8 sq. mi = 1.77 inches.

The average curve number for 1.77 inches of runoff from a rainfall of 4.45 inches is 72 (from Figure 4).

Time of Concentration

The time of concentration is defined as the time it takes for rainfall to travel from the hydraulically most distant part of the watershed to the outlet of the subbasin. For this report the time of concentration (Tc) was determined as follows:

$$Tc = \text{Length (feet)}/(V \times 3600)$$

V is a velocity term (ft/sec) which is defined by the equation, $V = KS^{.5}$, where S = slope in percent for a particular segment and K varies according to the following flow regimes:

$V = 2.1S^{.5}$ (for small tributaries, and swamps with channels)
$V = 1.2S^{.5}$ (waterways, flow through swamps without channels and valleys well defined by contours)
$V = .48S^{.5}$ (sheet flow)

The following is an example on how Tc can be computed for a subwatershed.

Type	Length (ft)	Elev.	Slope %	K	$V=KS^{.5}$	Tc = Length/3600V
sm trib	2520	728-692	1.43	2.1	2.51	.28
sm trib	4800	826-728	2.04	2.1	3.00	.44
waterway	3010	934-826	3.59	1.2	2.27	.37
waterway	1660	954-934	1.20	1.2	1.31	.35
						1.44 hrs.

The Tc for this subwatershed is 1.44 hours.

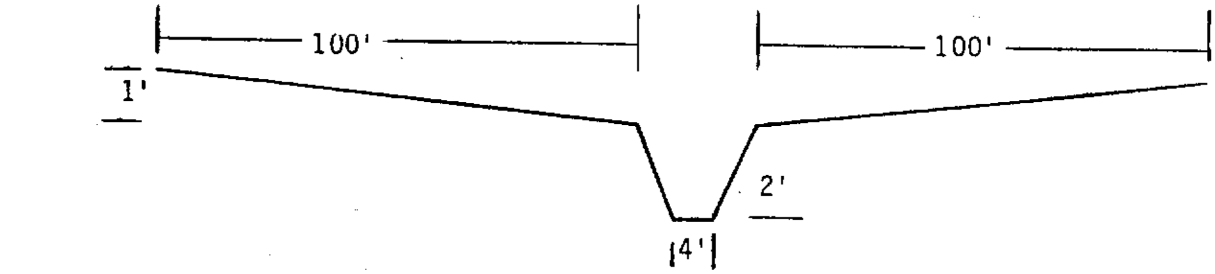
The number of segments used to determine the total Tc within each subwatershed is dependent on the slope. Segment lengths should be picked which have uniform slopes. In looking at future conditions, it is expected that the Tc would be shortened due to development as a result of paving, curb and gutters and storm sewers. For this report, the Tc for future conditions was shortened by assuming that all of the segments were small tributary where K = 2.1. With the above example, the future Tc would be 1.13 hours. Shorter Tc's result in higher flood peaks.

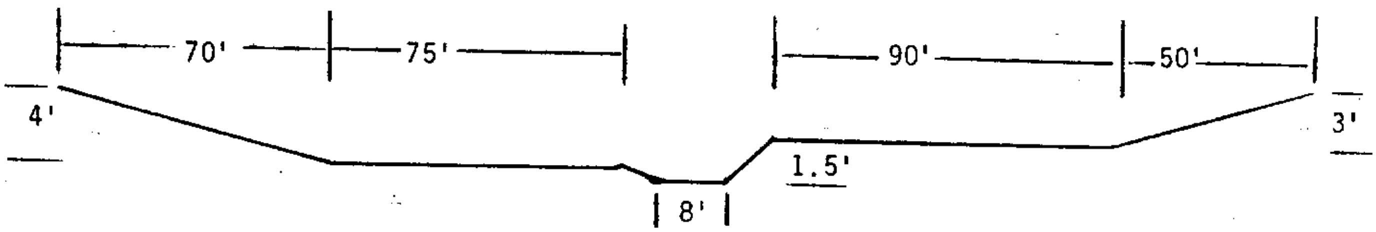
Stage-Storage-Discharge

Stage-storage-discharge relationships were estimated for several of the road crossings which were thought to be restrictive enough (small culverts with substantial road fill) to be able to attenuate (lower) flood flows. Storage available behind the road crossings was estimated from the USGS quadrangle. A better storage relationship could have been developed if more detailed contour information was available. Stage-storage-discharge relationships were developed for the following road crossings: Garfield Road at subbasins 5a and 7b; Emerson Road at subbasins 1 and 2 combined; and Hammond Road at subbasins 3 and 5 combined, 7a, 9, 10, 13, 21 and 24. Some survey data was provided by Gosling Czubak for some of the road crossings. Other information, such as the height of road fill, pipe length and size, was estimated or measured during a field survey.

Cross-Section, Reach Lengths

Reach lengths from one subbasin to the next were measured off the USGS quadrangle. A uniform cross-section shape was estimated from field observation and is shown below. This was used for the upper areas.





cross-section used in lower reaches

Modeled Scenarios

To evaluate the effect on flows due to future development, three scenarios were simulated.

1) Existing conditions based on 1978 land use information

2) Developed conditions - Assuming ¼ acre residential development throughout the watershed.

3) Developed conditions - Assuming future conditions based on zoning plans.

The 24 hour duration rainfall frequencies for this area are listed in Table 5 below. These were taken from Technical Paper 40 (TP40, Reference 13).

Table 5
Rainfall Frequencies

1 year 24 hour =	1.95 inches
2 year 24 hour =	2.20 inches
5 year 24 hour =	2.85 inches
10 year 24 hour =	3.2 inches
25 year 24 hour =	3.65 inches
50 year 24 hour =	4.1 inches
100 year 24 hour =	4.45 inches

For this model, a Type 1 rainfall distribution (Appendix B) was used with the 2 year, 25 year and 100 year rainfall frequencies. These rainfall frequencies were chosen to correspond to criteria being developed in a draft ordinance by local officials.

Table 6 lists the subbasins and drainage areas along with the curve numbers and times of concentration for each of the 3 scenarios. Although the noncontributing area was not included in the future scenarios, an argument could be made that these areas would be connected or drained and would contribute additional runoff to the watershed.

Table 7 lists flows at four locations in the watershed for the 2-year, 25-year and 100-year frequency storms for each of the three scenarios.

TABLE 6

Comparison of Curve Numbers and Times of Concentration

Sub-Watershed	Drainage Area (mi^2)	1978 Conditions CN	1978 Conditions Tc(hrs.)	¼ Acre Devel. CN	¼ Acre Devel. Tc(hrs.)	Zoned Condition CN	Zoned Condition Tc(hrs.)
1	.78	66	1.44	71	1.13	64	1.13
2	.96	63	1.18	67	.78	59	.78
3	.14	63	.35	73	.29	91	.29
4	.33	59	1.30	63	.75	54	.75
5A	.08	64	.30	73	.19	93	.19
5B	.04	66	.26	75	.21	91	.21
6	.15	69	.31	72	.28	83	.28
7A	.17	61	.49	69	.28	61	.28
7B	.39	61	.66	68	.55	68	.55
7C	.02	69	.18	75	.15	81	.15
8	.88	68	1.95	75	1.62	82	1.62
9	.30	56	.63	70	.51	67	.51
10	.33	71	.89	76	.51	92	.51
11	.45	75	1.23	78	.97	90	.97
12	.10	71	4.04	74	1.03	77	1.03
13	.61	61	1.35	72	.83	63	.83
14	.39	70	1.33	73	.92	92	.92
15	.27	49	1.45	61	1.08	84	1.08
16	.74	65	.80	72	.62	63	.62
17	.56	67	1.67	74	1.49	89	1.49
18	.35	57	5.90	66	1.48	57	1.48
19	.55	50	1.01	62	.58	56	.58
20	.19	70	.61	79	.56	76	.56
21	1.03	57	2.01	69	1.14	62	1.14
22	.84	67	1.23	75	.85	74	.85
23	.06	79	.84	87	.61	85	.61
24	.86	58	1.24	67	.83	57	.83
25	.43	74	1.27	78	1.19	78	1.19
26	.07	78	.62	86	.52	84	.52
	12.1						

TABLE 7

Comparison of Flows for the Three Development Scenarios
(flows in cfs)

		1978 Conditions			¼ Acre Development			Zoned Conditions		
	DA(mi^2)	2-yr.	25-yr.	100-yr.	2-yr.	25-yr.	100-yr.	2-yr.	25-yr.	100-yr.
Mitchell Creek @ Townline Road	5.1	40	200	310	90	330	480	210	500	670
Mitchell Creek u/s of Four Mile Creek	8.0	60	310	500	140	520	790	340	890	1240
Four Mile Creek @ Mitchell Creek	4.0	30	190	340	90	410	620	80	340	540
Mitchell Creek d/s of Four Mile Creek	12.1	90	480	820	210	880	1340	420	1230	1780

As shown in Table 7, increased development without any detention or retention requirements will substantially increase flows throughout the watershed which could lead to potential environmental problems as discussed in the introduction. Because of the sandy soils in this watershed, there is very little runoff for existing conditions for the lower frequency storms. There is a 3-5 fold increase in the 2-year flows as opposed to a 2-3 fold increase in the 100-year flows. Table 8 lists the 2-year, 25-year and 100-year flows for each subwatershed for the three scenarios. Increases in flows for some of the individual subbasins is even more dramatic. For instance, with subbasin 10, the curve number increases from 71 with existing conditions to 92 with the zoned conditions. This results in a 2-year flow increase from 10 cfs to 120 cfs and a 100-year increase for 100 cfs to 300 cfs.

Several of the road crossings which were modeled with stage-storage-discharge relationship are effective in attenuating flood flows. Any future road project which enlarges an existing small culvert that has 4-5 foot of road fill or more should be evaluated as to downstream impacts. A larger bridge or culvert will allow a higher flood peak to pass downstream, thereby increasing the potential flooding problem. These restrictive culverts are, in a manner of speaking, acting as detention ponds.

Table 9 lists the road crossings and the inflows and outflows for each of the three development scenarios. If some of these sites were to be used as a regional detention site similar to subbasin 16, then more detailed surveys would have to be done. For this study, some of the road low points and culvert lengths were estimated and the overflow weir length was set at 100 feet.

Proposed Ordinance

A proposed county stormwater ordinance was drafted by the Drain Commissioner's Office and other local groups in Grand Traverse County. The draft ordinance states that as a minimum any detention, retention and infiltration basin shall have the storage capacity to hold the increase in runoff caused by a proposed project based on a 25-year 24-hour storm. The runoff volume should be released over a 24-hour period at a peak discharge release rate not to exceed .2 cfs/acre or the 2-year 24-hour peak based on grassed undeveloped conditions, whichever is less. There is also a special provision calling for storage of runoff from back to back 100-year storms when downstream flooding or water quality concerns are critical.

<u>The following is an example of the effects of the retention/detention requirements of this ordinance.</u>

A 50 acre site on B soils currently in a meadow condition (CN = 58) will be developed into a commercial site (CN = 92). Time of concentration = 1.0 hours.

TABLE 8

Comparison of Flows for Each Subbasin

Sub-Watershed	Drainage Area (mi^2)	1978 Conditions			¼ Acre Development			Zoned Conditions		
		2-yr.	25-yr.	100-yr.	2-yr.	25-yr.	100-yr.	2-yr.	25-yr.	100-yr.
1	.78	9	75	130	25	130	200	7	65	120
2	.96	8	70	140	14	130	230	5	50	110
3	.14	1	17	35	10	45	70	55	110	140
4	.33	2	14	30	3	30	60	1	7	20
5a	.08	1	12	20	6	30	45	35	70	90
5b	.04	1	8	13	4	15	25	16	35	40
6	.15	4	35	60	8	45	70	30	80	120
7A	.17	1	13	30	5	40	70	1	16	35
7B	.39	3	25	60	8	70	120	8	70	120
7C	.02	1	5	9	2	8	12	4	11	16
8	.88	13	85	140	40	160	240	90	240	330
9	.30	1	9	25	9	65	100	5	50	85
10	.33	10	60	100	30	110	160	120	230	300
11	.45	25	95	140	40	130	180	110	230	300
12	.10	2	8	13	5	20	35	7	25	40
13	.61	4	35	70	25	120	200	5	50	100
14	.39	9	55	90	17	80	130	110	220	280
15	.27	*	3	6	2	16	35	40	100	140
16	.74	8	80	150	30	170	270	6	70	140
17	.56	7	55	95	25	100	150	100	220	290
18	.35	1	8	15	4	30	60	1	11	25
19	.55	1	7	16	4	45	100	2	17	45
20	.19	5	40	60	20	70	100	15	60	90
21	1.03	4	35	90	20	140	240	7	70	140
22	.84	12	90	160	50	210	320	45	200	300
23	.06	6	20	30	14	30	45	12	30	40
24	.86	4	30	75	13	110	200	3	30	75
25	.43	20	80	130	30	110	160	30	110	160
26	.07	7	25	35	16	40	50	14	35	50
	12.1mi^2									

*Flow was computed to be less than 1 cfs using this methodology.

TABLE 9
Comparison of Inflows and Outflows
at Road Crossings for Various Scenarios

Roads Estimated Top of Road	Subbasins Drainage Area (mi^2)	1978 Conditions			¼ Acre Development			Zoned		
		2-yr.	25-yr.	100-yr.	2-yr.	25-yr.	100-yr.	2-yr.	25-yr.	100-yr.
Emerson 700.8	SB 1&2 1.74	17/14 694.4	140/60 699.9	180/160 701.3	35/20 695.1	250/120 701.1	420/350 701.8	11/10 694.1	110/50 698.2	230/110(A) 701.1(B)
Garfield 683.8	SB 5A .41	1/1 676.0	12/7 677.6	20/10 679.0	6/3 676.6	30/10 679.1	45/11 679.4	35/11 679.3	70/12 680.2	90/13 680.8
Hammond 659.0	SB 3&5 2.33	16/14 656.2	70/70 659.2	180/160 659.6	25/20 658.5	130/130 659.5	330/260 659.8	80/20 657.8	150/75 659.3	190/140 659.5
Hammond 684.3	SB 7A .17	1/1 670.5	13/4 671.9	30/6 673.5	5/2 670.8	40/6 673.5	65/8 675.8	1/1 670.5	15/4 671.9	35/6 673.5
Garfield 656.1	SB 7B .56	4/3 651.0	30/9 653.3	60/12 655.5	8/5 651.6	70/11 655.2	120/25 656.1	8/4 651.4	70/11 654.7	120/25 656.1
Hammond 682.9	SB 9 .30	1/1 671.6	9/8 671.78	25/20 672.1	9/7 671.8	65/30 673.3	100/45 675.1	5/4 671.7	50/25 672.8	85/40 674.3
Hammond 669.3	SB 10 .33	10/6 663.3	60/25 665.9	100/30 668.0	30/12 663.9	110/30 667.4	160/50 669.3	120/30 667.9	230/110 669.7	300/180 669.9
Hammond 683.0	SB 13 .61	4/4 677.3	35/15 680.5	70/25 683.0	25/12 679.3	120/45 683.1	200/140 683.5	5/5 677.5	50/20 681.1	100/35 683.1
Drop Inlet @695.5 Road @699	SB 16 .74	8/6 695.7	80/30 696.3	150/60 696.8	30/12 695.9	170/60 696.8	270/110 697.4	6/5 695.7	70/25 696.2	140/50 696.6
Hammond 728.3	SB 21 1.03	4/4 706.0	35/25 709.7	90/35 713.4	20/15 708.2	140/40 716.5	240/50 720.6	7/7 706.5	70/30 712.0	140/40 717.0
Hammond 700.8	SB 24 .86	4/4 693.0	30/25 696.0	75/40 699.1	13/11 694.1	110/40 699.7	200/90 701.0	3/3 692.9	30/20 695.7	75/35 698.9

(Flows in cfs)
(A) 230/110 inflow outflow; (B) 701.1 estimated water surface elevation upstream of road

The difference in runoff volume between existing and proposed conditions for a 25-year 24-hour rainfall of 3.65 inches is computed as follows:

<u>Proposed:</u> CN = 92
R.O. = 2.78 inches x 50 acres = 139 acre-in = 11.6 acre-ft

<u>Existing:</u> CN = 58
R.O. = .51 inches x 50 acres = 25.5 acre-in = 2.1 acre-ft

The developed site must provide retention/detention for 9.5 acre-feet (11.6 - 2.1). This volume should be released over a 24 hour period with the peak being the lesser of .2 cfs/acre x 50 = 10 cfs or the 2 year 24 hour flow which in this case is less than 1 cfs.

The 2 year, 25 year and 100 year flows for existing and proposed conditions for this site are as follows:

	Existing	Proposed	Proposed with Retention
Q100	7 cfs	55 cfs	7 cfs
Q25	3 cfs	40 cfs	3 cfs
Q2	<1 cfs	20 cfs	1 cfs

To arrive at the flows with retention in place, the following stage-storage-discharge relationship was used.

Stage	100	102	104	104.5	105
Storage (acre-ft)	0	5	9.5	10.7	11.9
Discharge cfs	0	.5	1	25	70

The pond would have 9.5 acre-ft of storage with a 1 cfs release rate before it was overtopped. If the pond was four feet deep before it overtopped, then the surface area would be about 2.5 acres or 5% of the 50 acre site.

For this site the retention policy appears to be effective in controlling the effects of urbanization and would benefit both water quantity and quality concerns. Either infiltration or some type of extended detention which would encourage settling would provide the best water quality protection. It is very important for this watershed that requirements protecting both the water quantity and quality aspects be adopted and enforced.

Note

When using a 2 year 24-hour rainfall with the curve number procedure, very little runoff is produced when the curve number is low. This methodology is okay if it is being used as a design criteria. However, the actual 2 year flow may be higher than this computed value because the 2 year flow is often dependent on springtime snowmelt conditions and not necessarily a rainfall event. A drainage area ratio to a gaged stream of similar hydrologic characteristics may be a more appropriate way of estimating an actual 2 year flow.

Low Flow Analysis

Flow measurements were made at 10 locations (Figure 5) in the watershed during the study. Flows were also made in previous years by the United States Geological Survey (USGS). These flows are listed in Tables 10 and 11. The drainage area shown at each site is the total drainage area including noncontributing areas. These areas contribute ground water to the system which supplies the baseflow in the streams. Flows were also measured by Battelle as part of their sampling process. Many of the USGS flows were measured on the West Branch of Mitchell Creek only. In order to estimate what the total flow was for Mitchell Creek near the mouth, it was assumed that 60% of the flow went down the West Branch. This estimate was based on the four measurements made this summer on the West Branch which averaged 61% of the total flow. A correlation using some of these flow measurements versus same day flows on the Boardman at Traverse City Gage #04127500 was used to estimate flow statistics on the Mitchell Creek. This correlation is shown in Figure 6. The estimated monthly mean and 50% and 95% exceedance flows for Mitchell Creek at the mouth (15.8 mi^2) are listed below in cfs.

MITCHELL CREEK @ THE MOUTH (DA = 15.8 mi^2)

	J	F	M	A	M	J	J	A	S	O	N	D
Mean Mon.	9.7	9.5	13	22	15	12	10	8.8	9.4	10	11	11
50%	9.6	9.2	11	20	14	11	9.4	8.6	8.8	9.7	11	11
95%	6.6	6.3	6.9	10	8.8	7.1	6.1	6.0	5.9	6.2	6.5	6.8

The 95% exceedance flow means that we would expect that much or more water in the stream 95% of the time when averaged over a long period of time. The estimated annual flow duration for Mitchell Creek at 15.8 mi^2 in cfs is:

10%	19
25%	13
50%	10
70%	8.8
75%	8.4
90%	7.0
95%	6.6

The estimated average annual flow is 12 cfs.

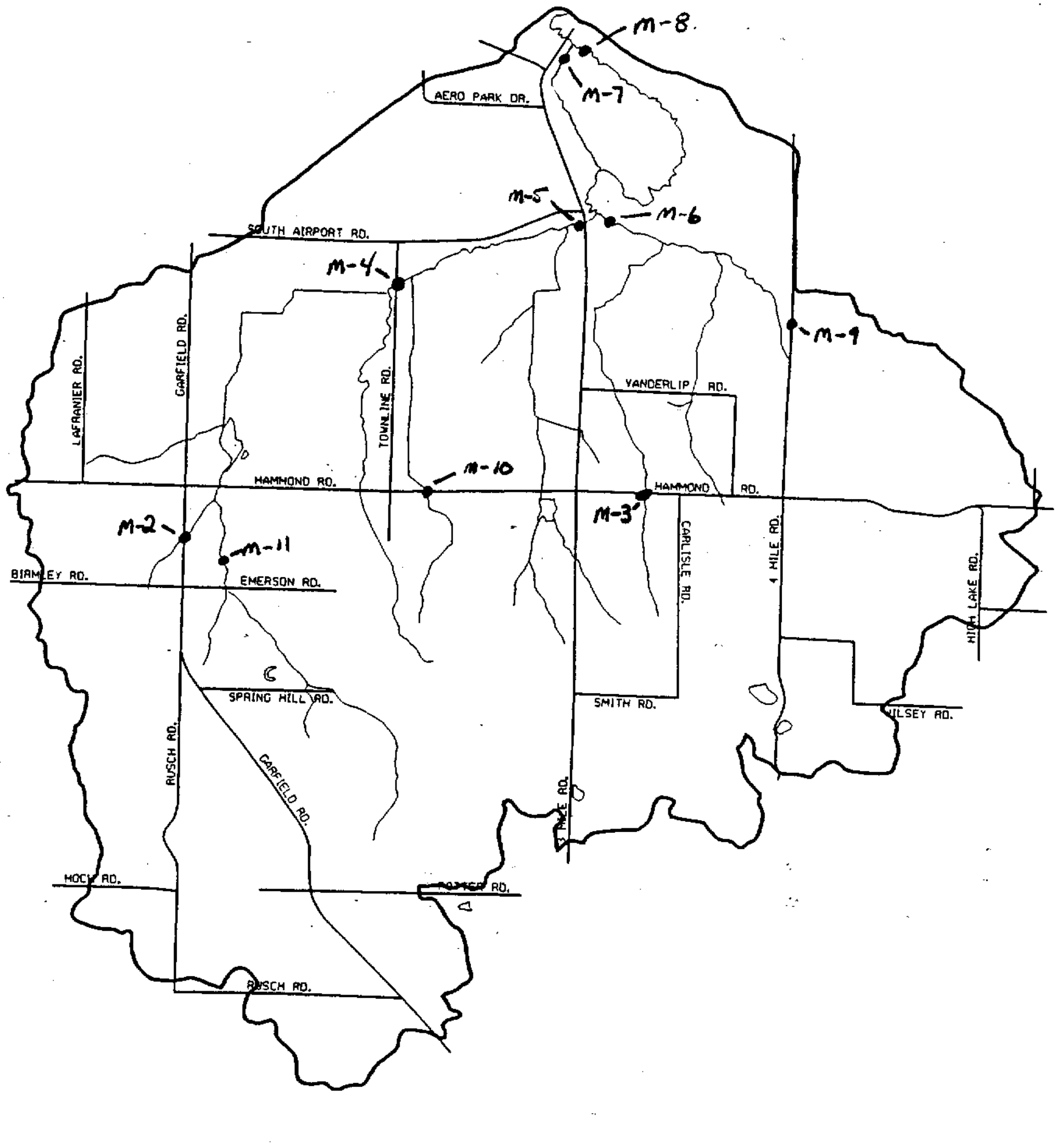


FIGURE 5

LOCATION OF MEASUREMENTS

TABLE 10
1991 Flows Measured by DNR
flows in cfs

Site	Watercourse	DA (mi^2)	Date	Flow	Yield (cfs/mi2)
M-2	Tributary	.6	3/12/91	.08	.13
			5/16/91	.09	.15
			5/17/91	.18	.30
			8/2/91	.06	.10
M-3	Vandorli Cr.	.9	3/11/91	.61	.68
			5/16/91	.45	.50
			5/17/91	1.21	1.34
			8/2/91	.3	.33
M-4	Mitchell Cr.	6.6	3/12/91	6.36	.96
			5/17/91	8.86	1.34
			8/2/91	5.62	.85
M-5	Mitchell Cr.	9.7	3/11/91	9.03	.93
			5/17/91	7.45	.77
			8/2/91	4.44	.46
M-6(A)	Four Mile Cr.	4.6	3/11/91	6.67	1.45
			5/17/91	8.55	1.86
			8/2/91	5.52	1.20
M-7	W. Br. Mitchell	*	3/11/91	10.6	
			5/17/91	8.94	
			5/26/91	12.3	
			8/2/91	4.78	
M-8(B)	E. Br. Mitchell	*	3/11/91	7.30	
			5/17/91	6.06	
			5/26/91	5.80	
			8/2/91	3.65	
M-9	Tributary	.07	3/11/91	1.18	16.9
			5/17/91	1.17	16.7
			8/2/91	1.26	18.0
M-10	Tributary	.6	3/11/91	1.06	1.77
			3/16/91	.94	1.57
			8/2/91	1.11	1.85
M-11	Tributary	3.0	3/12/91	.17	.06
			5/16/91	.12	.04
			5/17/91	.26	.09
			8/2/91	.13	.04
3 Mile Rd.	Mitchell	15.8	3/11/91	17.9	1.13
			5/17/91	15.0	.95
			5/26/91	18.1	1.14
			8/2/91	8.43	.53

(A) Flow @ M-5 was subtracted from combined M-5 & M-6 flow to get flow @ M-6.
(B) Flow @ M-7 was subtracted from combined M-7 & M-8 flow to get flow @ M-8.
* Drainage area is indeterminant
- Flows on 5/17/91 & 5/26/91 were runoff events.

TABLE 11

Flows Measured by USGS

			Date	Flow	Yield
Mitchell Creek at 3 Mile Road	(M-5)	DA = 9.7	12/22/82	7.07	.73
			2/1/83	7.44	.77
			3/2/83	9.03	.93
			7/20/83	2.83	.29

			Date	Flow	Date	Flow
W. Br. Mitchell Creek	(M-7)	DA = *	5/13/49	9.15	3/27/85	27.5
			6/10/49	7.37	4/24/85	13.2
			8/25/79	5.11	6/4/85	7.41
			12/22/82	8.53	7/16/85	4.7
			2/1/83	9.55	8/20/85	6.8
			3/2/83	10.5	9/25/85	13.6
			7/20/83	4.92	10/30/85	8.10
			6/19/84	17.3	12/11/85	11.4
			7/31/84	5.09	1/16/86	9.53
			9/6/84	6.54	2/21/86	12.5
			10/10/84	7.47	4/3/86	12.2
			11/8/84	8.51	5/6/86	8.35
			12/4/84	9.14	6/5/86	6.70
			1/9/85	9.00	8/27/86	8.18
			2/12/85	8.78		

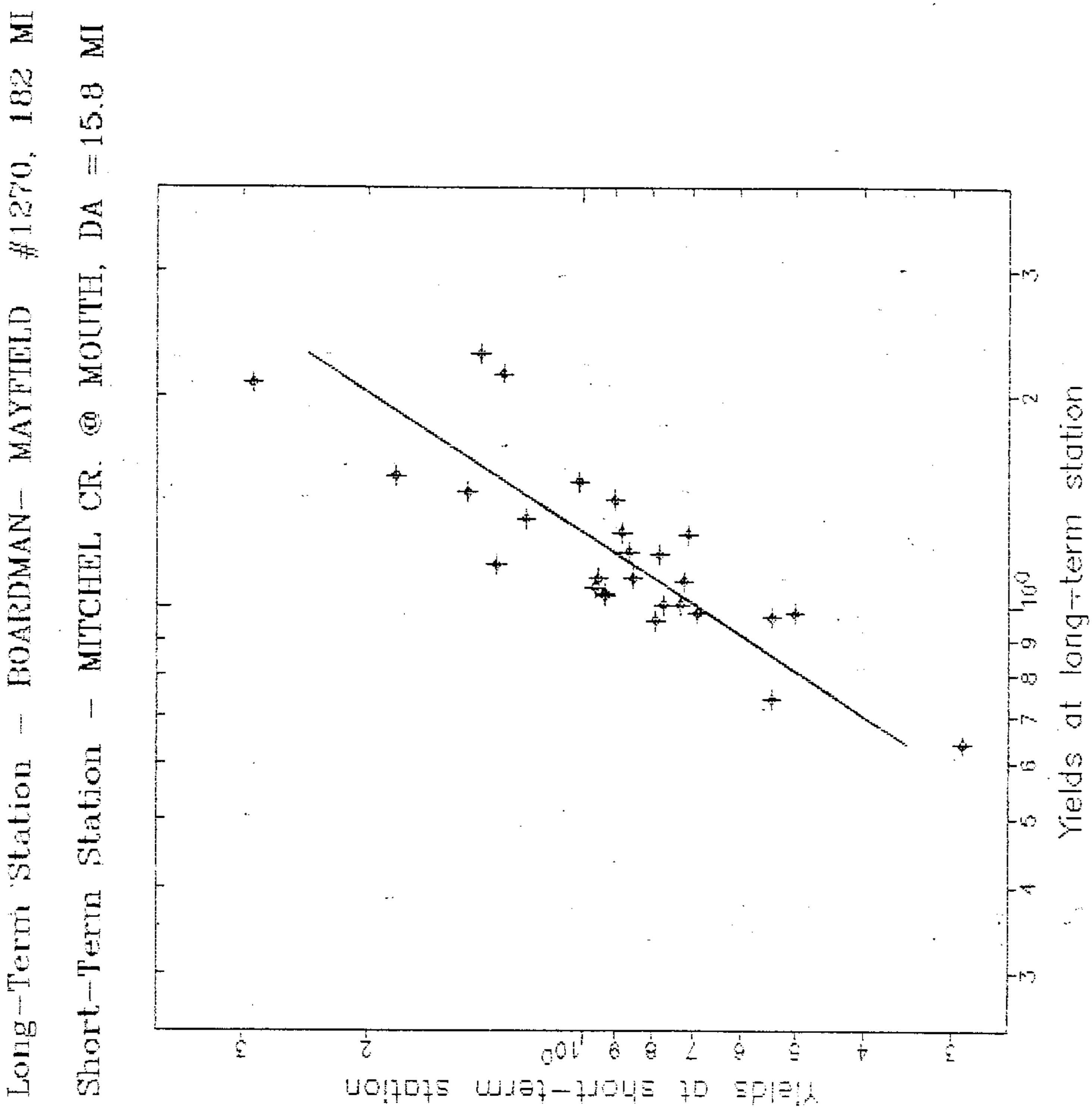


FIGURE 6

MITCHELL CREEK vs BOARDMAN RIVER CORRELATION

Urbanization Impacts on Water Quality

Urbanization can cause substantial increases in the volume and rate of runoff from a watershed. Those increases tend to cause physical changes and degradation to the stream's water quality. Increased flows lead to channel scour and increased sedimentation. Urbanization can lead to increased stream temperature and increased pollutant levels due to more paved areas which collect oil, grease, sediment and other pollutants. These are then transported via curb and gutter and storm sewers to the stream system. Nitrogen and phosphorous levels may increase in urban area streams. This may be critical if there are lakes or ponds in the system or slow moving reaches in the stream. Concentrations of metals and pesticides may increase depending on the land use in the watershed. Bacteria levels may also increase which have caused some streams and lakes in Michigan to become unsuitable for human contact for periods of time.

Minimizing Both Water Quantity and Quality Impacts

Traditionally, urban drainage problems have been solved by getting rid of the water as quickly as possible and transporting it downstream. This was done by making the conveyance system large and efficient either with larger culverts, ditches or both. While this method may have temporarily solved the upstream problem, it only passed on and increased the problem downstream. This lead to regulations calling for detention ponds to be built which are designed to release flows at a specified release rate, usually the predevelopment rate. This can reduce the increase in downstream flows if done properly. Often the detention policy is applied to the entire watershed, even though detention in some portions of the watershed may cause an increase in flows due to the timing of the hydrographs (see Figures 7a, b, c). Detention in downstream portions of the watershed may delay the peaks from those areas so much that when added to upstream peaks the combination is higher than if there wasn't any detention in the downstream areas. This is where modeling can be beneficial. It can be used to comprehensively evaluate the entire watershed.

In addition to potentially causing downstream flooding problems, the traditional techniques do not address the problems of water quality degradation caused by the increased pollutant levels of the urban setting. The traditional techniques are usually sized for design storms ranging from 5 year to 25 year frequencies. If there are detention ponds they usually have an outlet at the bottom of the pond where everything eventually drains out with little or no settling. These detention ponds may reduce the peak outflows to pre-existing rates which will help in preventing increased channel erosion due to increased flows and velocities. They do not, however, address the concerns of additional pollutants, including sediment being delivered to the stream due to urbanization. Most of these pollutants are picked up and transported to the stream during the small rain events which produce runoff. From a water quality standpoint, these small rainfall events, up to 2 year rainfall, need to be designed for using infiltration, extended detention or wet ponds where settling can occur over a 24-48 hour period. This is in addition to maintaining predevelopment flow rates for the higher frequency storms.

The amount of runoff volume which is designed for using infiltration, extended detention or wet ponds varies across the county. Some of the criteria are listed below:

- runoff volume equal to ½ inch per acre of impervious area
- runoff volume equal to ½ inch per acre of contributing area
- runoff volume equal to amount generated by one inch storm
- runoff volume equal to the amount generated by a 1 year or 2 year 24 hour storm

In Michigan it usually rains ½ inch or more about 18-24 times a year. A rainfall of 1 inch or more will occur approximately 7-8 times a year. A 1 year 24 hour storm ranges from 1.8 inches in northern Michigan to 2.4 inches in southern Michigan, while the 2 year 24 hour storm ranges from 2 inches to 2.7 inches.

When feasible, infiltration should be the preferred method for water quality design. The infiltration rates of the underlying soils must be .52 inches/hour or greater. This rate is normally found with A and B type soils (Table 1). Typical design configuration for extended dry detention basins and wet ponds are shown in Figures 8 and 9. A 1991 Stormwater Management Guidebook by the Michigan Department of Natural Resources describes various design considerations for extended wet and dry detention, infiltration basins, grassed swales and oil and grease separators.

Figure 10 by Schueler lists various BMP's with drainage areas for which they are estimated to be effective for. Figure 11 also by Schueler lists various BMP's and the types of soils for which they may be effective.

Some other types of BMP's which can help in the urban setting are:

1) Buffer or greenbelt areas along all streams and wetland. No ground may be disturbed in this area. Buffer widths requirements vary across the country from 25 feet to 200 feet.

2) Sediment sumps in storm sewers - should be cleaned out when they are 60% full. Cleaned at least twice a year, before first snowfall and after spring snowmelt.

3) Maintaining as much vegetation and green area as possible.

4) Using grassed swales instead of curb and gutter.

5) Disconnecting downspouts from the storm sewers.

Temperature Considerations

High quality streams are usually very temperature dependent. Slight increases in water temperature may seriously decrease or eliminate sensitive fish species such as trout. A study by Galli (1990) done in Maryland found that the temperature of an urban stream increased linearly .14° F per 1% increase in imperviousness. Thus, a 60% increase in imperviousness within a watershed would raise the stream temperature 8.4° F. The study also noted that vegetation and canopy cover along streams helps to control the rise in water temperature during the summer. Removal of this vegetation and canopy could cause a rise in temperature of 11-20° F in the summer with associated cooler winter temperatures. On smaller streams water temperatures may increase 1.5° F per 100 feet when flowing through unshaded areas. The study indicates that trout and other cold water biota may not be able to survive when the watershed imperviousness exceeds 12-15%. If temperature control is a critical element with a stream, then land use controls, stream buffer requirements and other BMP's which limit temperature increases are important. Galli found that infiltration is the best alternative when temperature is critical. Shading of the pond and the inflow and outflow channels of the detention/retention ponds was also found to be important.

Construction Site Erosion

Soil erosion from new construction sites, including roads, appears to be a major concern in many areas of the state. Critical wetlands and stream reaches have been destroyed due to poor soil erosion practices. Adequate soil erosion control, enforcement and follow-up are needed in watersheds where development pressure is occurring.

A 1990 study by Scheuler and Lugbill on "Performance of Current Sediment Control Measures at Maryland Construction Sites" had the following findings and recommendations.

- Vegetative stabilization and other erosion control measures are the first and most important aspect in preventing off-site movement of sediment. These measures must be established quickly, maintained and inspected.

- The performance of the sedimentation erosion controls is greatest in the early part of construction when the amount of imperviousness is still minimal.

- When possible do the construction in a staged manner. Avoid clear cutting and grading the entire site at once. Work on one area and let it stabilize before moving on.

- Restrict development in environmentally sensitive areas and possibly use cluster development which minimizes the disturbed area.

- The study recommends a sediment basin volume of 3600 cubic feet/acre with a combination of wet and dry storage. The wet storage helps against resuspension of sediments.

- 60% of the sediment was removed in 6 hours, 90% was removed after 48 hours. Settling velocities are listed in Table 12 (Ref. 7). Detention times of at least 6 hours should be provided.

TABLE 12

Settling/Particle-Size Relationships

PARTICLE SIZE CLASSIFICATION	PARTICLE DIAMETER (microns)	SETTLING VELOCITY (ft/hr)
SAND		
Very Coarse	1000-2000	128
Coarse	500-1000	65
Medium	250-500	34
Fine	125-250	16
Very Fine	62-125	6
SILT		
Coarse	31-62	1.4
Medium	16-31	.4
Fine	8-16	.1***
Very Fine	4-8	.02***
CLAY	>4	.055***

(***Discrete particles in still water. Actual velocities may be 1.5 to 6 times less rapid.)

At a 1991 Stormwater Conference at Grand Valley State University, some of the following ideas were presented by Doug Sporte of the City of Kentwood on enforcing soil erosion (Ref. 10).

- Don't accept site plans unless they contain adequate soil erosion and stormwater controls.

- Require a performance bond for completion of soil erosion controls and site stabilization. Contact bond company if work is not completed.

- Make sure the contractor is working with the most recent set of plans.

- Issue a stop work order if violation is bad enough.

- Require a greenbelt buffer along all streams, drains, pond and wetlands.

- Limit floodplain activity.

- Stormwater and soil erosion control should be the first things built. Any permanent structure should be able to handle the entire site even if only a portion is being constructed now.

- Deny occupancy if final job is not stabilized and problems are not corrected.

FIGURES 7a, b, c
INCREASED FLOOD PEAK DUE TO DETENTION
REF. 3 and 5

Figure 7b

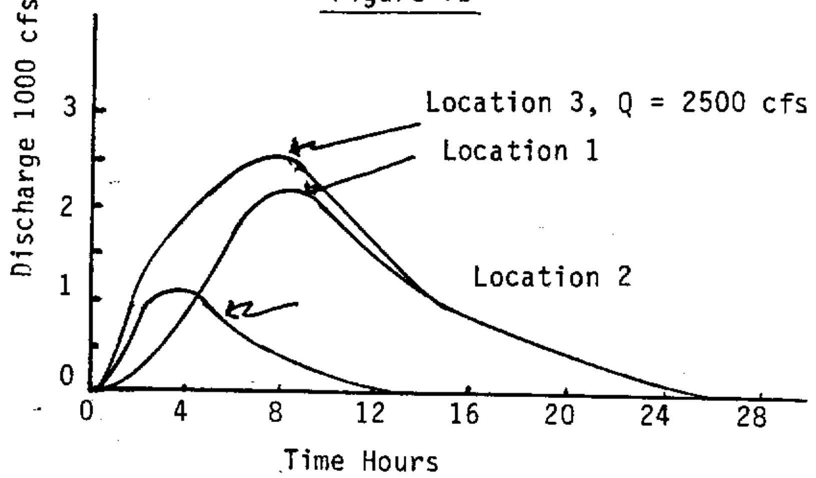
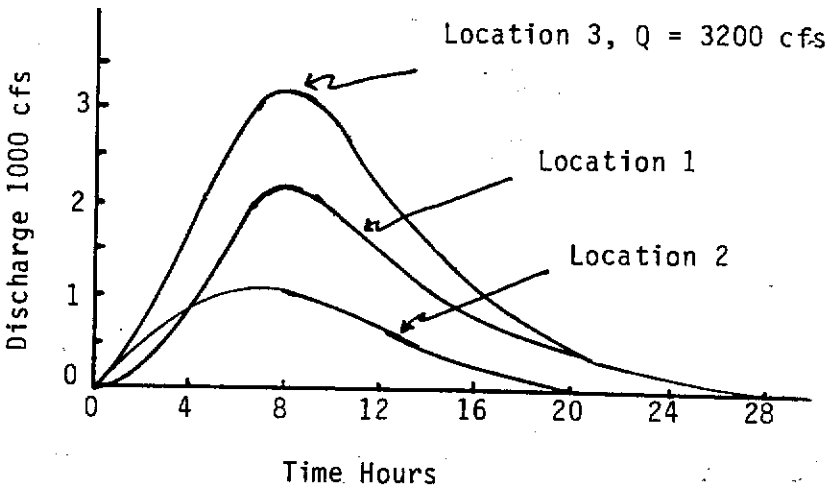


Figure 7c



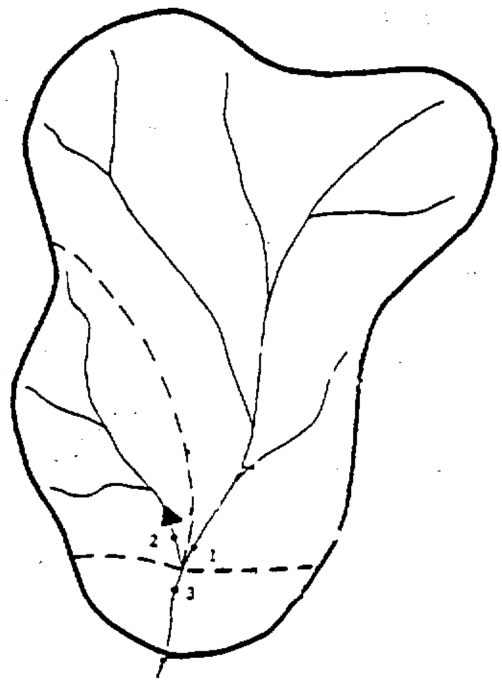


Figure 7a

Explanation

Figure 7b shows three hydrographs for undeveloped conditions at locations 1, 2 and 3 in Figure 7a. The hydrograph at location 3 with a peak discharge of 2500 cfs represents the combined flows of hydrographs 1 and 2. Figure 7c shows three hydrographs assuming area 2 was developed and had a dtention pond constructed. Even though the peak from area 2 is the same, it's timing is delayed enough so that when it is added to hydrograph #1, the resultant peak at location #3 increases to 3200 cfs.

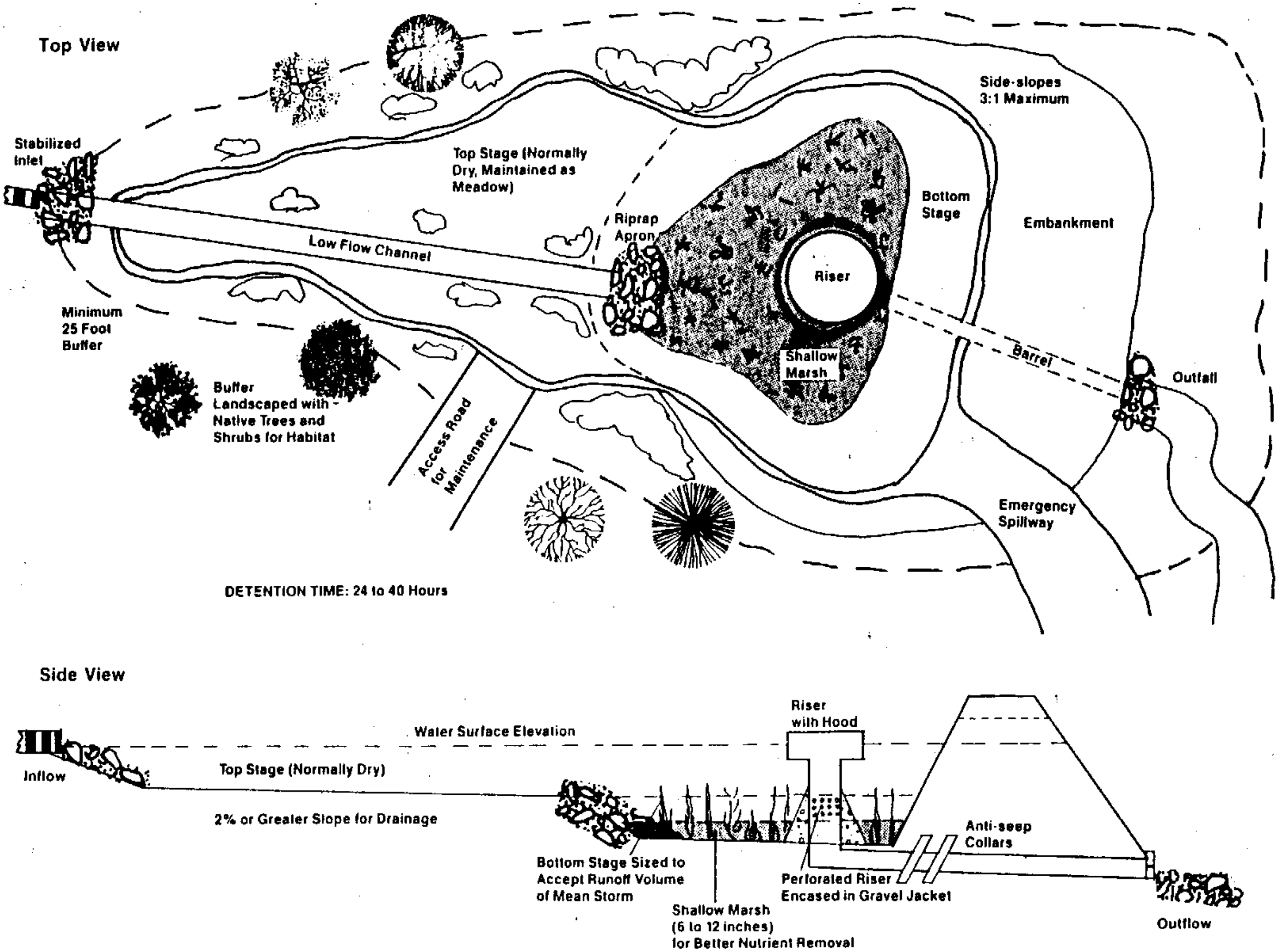


Figure 8 - **Extended Detention Pond**

Source - Schueler, 1987, Reference 6

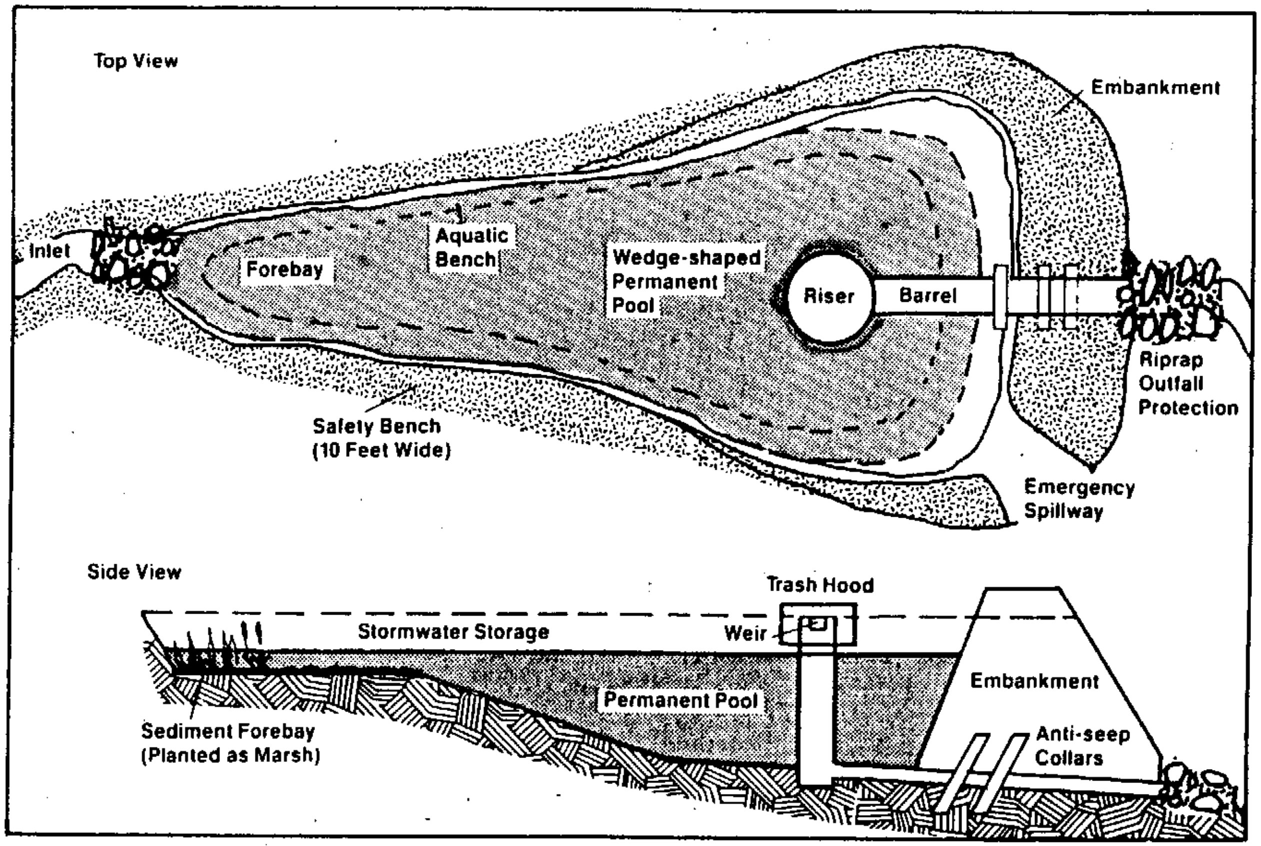


Figure 9 - **Wet Detention Pond**

Source: Schueler, 1987, Reference 6

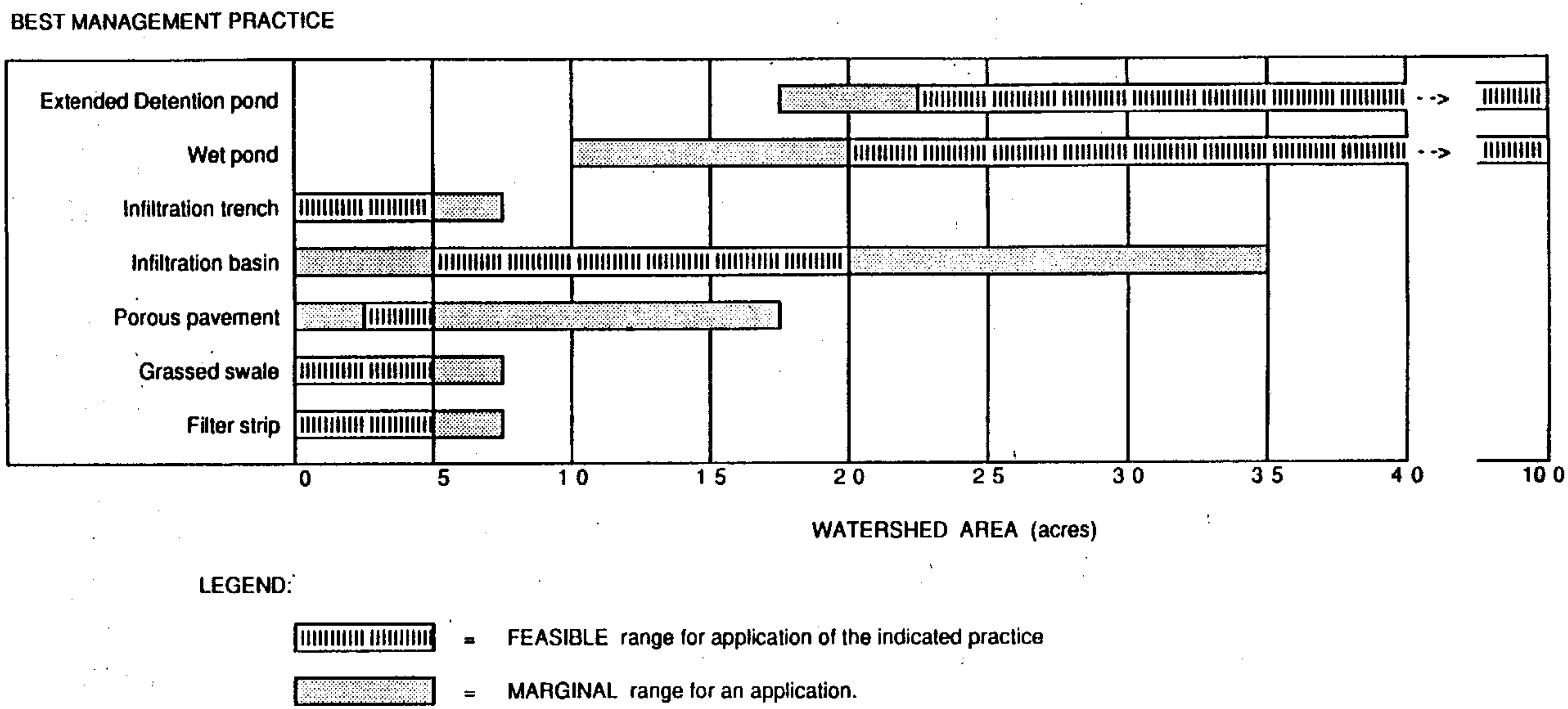


FIGURE 10 FEASIBLE BMP TYPES FOR DIFFERENT SIZES OF WATERSHED

(Ref. 6 & 14)

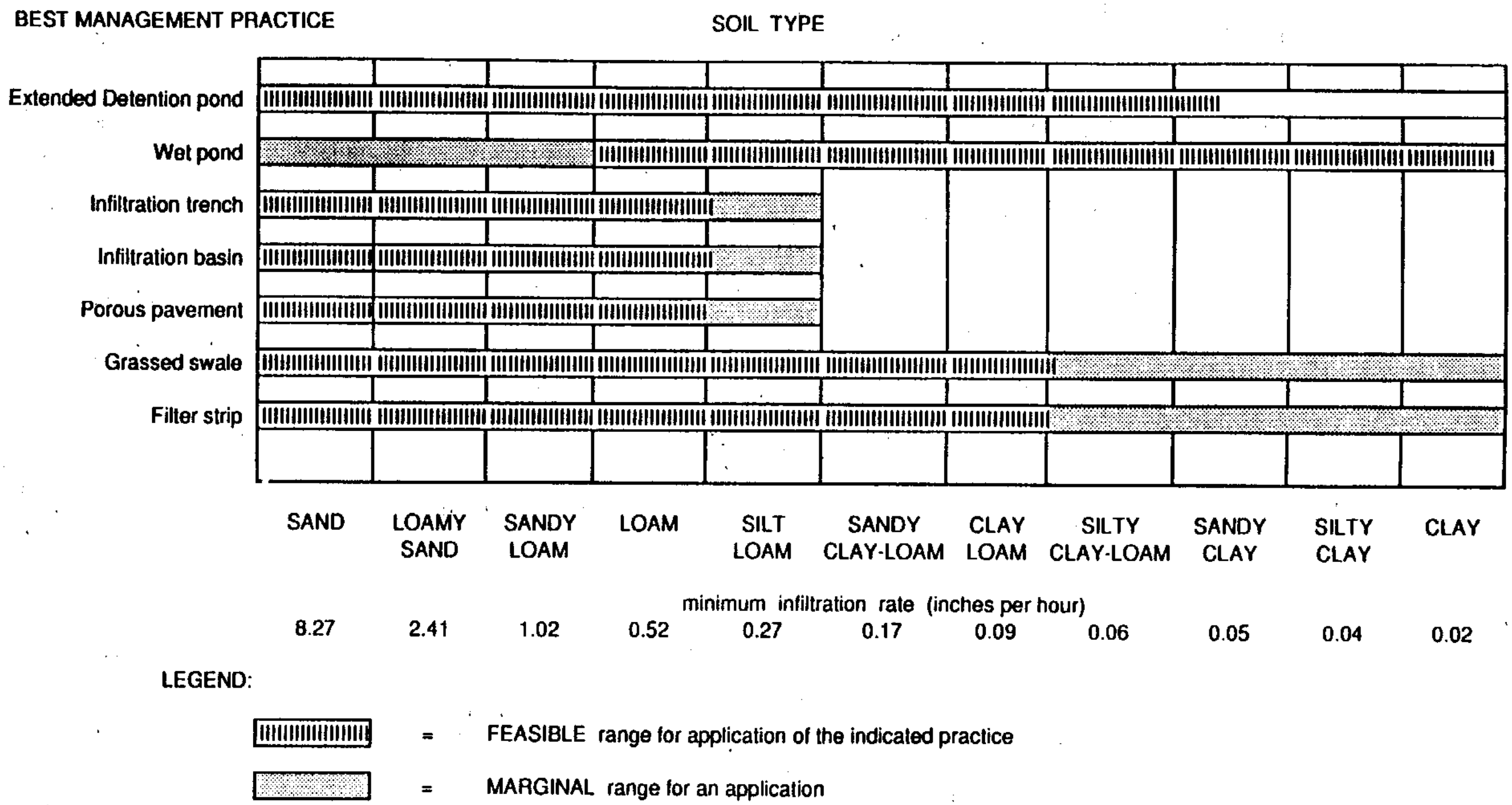


FIGURE 11 RESTRICTIONS FOR APPLICATION OF BMPs BASED ON SOIL PERMEABILITY

(Ref. 6 & 14)

APPENDIX A

Table 13

MIRIS

CURRENT LAND COVER/USE LEGEND

1 URBAN
- 11 RESIDENTIAL
  - 111 MULTI-FAMILY, HIGH RISE
  - 112 MULTI-FAMILY, LOW RISE
  - 113 SINGLE FAMILY, DUPLEX
  - 115 MOBILE HOME PARK
- 12 COMMERCIAL, SERVICES, INSTITUTIONAL
  - 121 PRIMARY/CENTRAL BUSINESS DISTRICT
  - 122 SHOPPING CENTER/MALL
  - 124 SECONDARY BUSINESS/STRIP COMMERCIAL
  - 126 INSTITUTIONAL
- 13 INDUSTRIAL
  - 138 INDUSTRIAL PARK
- 14 TRANSPORTATION, COMMUNICATIONS, UTILITIES
  - 141 AIR TRANSPORTATION
  - 142 RAIL TRANSPORTATION
  - 143 WATER TRANSPORTATION
  - 144 ROAD TRANSPORTATION
  - 145 COMMUNICATIONS
  - 146 UTILITIES
- 17 EXTRACTIVE
  - 171 OPEN PIT
  - 172 UNDERGROUND
  - 173 WELLS
- 19 OPEN LAND, OTHER
  - 193 OUTDOOR RECREATION
  - 194 CEMETERIES

2 AGRICULTURE
- 21 CROPLAND
- 22 ORCHARDS, BUSH FRUIT, VINEYARDS, ORNAMENTAL HORTICULTURE
- 23 CONFINED FEEDING
- 24 PERMANENT PASTURE
- 29 OTHER

3 NONFORESTED
- 31 HERBACEOUS
- 32 SHRUB

4 FORESTED
- 41 DECIDUOUS
  - 411 NORTHERN HARDWOOD
  - 412 CENTRAL HARDWOOD
  - 413 ASPEN/WHITE BIRCH ASSOCIATION
  - 414 LOWLAND HARDWOOD
- 42 CONIFEROUS
  - 421 PINE
  - 422 OTHER UPLAND CONIFER
  - 423 LOWLAND CONIFER
  - 429 CHRISTMAS TREE PLANTATION

5 WATER
- 51 STREAM
- 52 LAKE
- 53 RESERVOIR
- 54 GREAT LAKES

6 WETLANDS
- 61 FORESTED
  - 611 WOODED
  - 612 SHRUB, SCRUB
- 62 NONFORESTED
  - 621 AQUATIC BED
  - 622 EMERGENT
  - 623 FLATS

7 BARREN
- 72 BEACH, RIVERBANK
- 73 SAND DUNE
- 74 EXPOSED ROCK

APPENDIX B
TABLE 14

SCS 24 HOUR TYPE I RAINFALL 30 MINUTE INTERVALS

.000	.008	.017	.026	.035	.045	.055	.065	.076	.087
.099	.112	.125	.140	.156	.174	.194	.219	.254	.30
.515	.583	.624	.654	.682	.705	.727	.748	.767	.784
.800	.816	.830	.844	.857	.870	.882	.893	.905	.916
.926	.936	.947	.955	.965	.974	.983	.992	1.000	

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